

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

**MISSOURI-16 MILE CREEK
HIGGINS BROTHERS NO.1 DAM AND RESERVOIR
MEAGHER COUNTY, MONTANA
MT-30**

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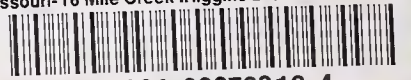
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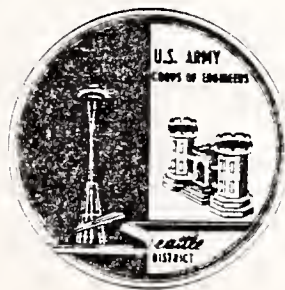


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EXECUTIVE SUMMARY

Under contract with the Seattle District Corps of Engineers and with representation from the State of Montana Department of Natural Resources and Conservation and the owner, Higgins Brothers No. 1 Dam was inspected by Hoskins-Western-Sonderegger, Inc., on 10 May 1979, under the authority of Public Law 92-367. Higgins Brothers No. 1 Dam is located in Meagher County, Montana, approximately 3.5 miles northeast of Ringling.

As design plans were not available for review, this report is based only on information obtained during an on-site inspection and analysis of hydrologic and hydraulic data. Findings were compared to engineering criteria currently accepted by most private and public agencies engaged in dam design, construction, and operation.

PRINCIPAL FINDINGS AND EVALUATIONS

Higgins Reservoir is intended to be used for irrigation storage and stock watering. The project consists of a dam on an unnamed tributary of Sixteenmile Creek, a diversion structure on Woodson Creek, and a canal leading from Woodson Creek to the reservoir. The reservoir has a drainage area of 2.0 square miles, a surface area of about 100 acres at normal pool, and storage at dam crest of 860 acre-feet.

In accordance with the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1), the 14.6-foot-high Higgins Brothers No. 1 Dam (MT-30) is classified as being of small size and as having a high (Category I) downstream hazard potential, due to the presence of the Higgins Ranch, the town of Ringling, U.S. Highway 89, and the C. M. St. P. & P. Railroad below the dam.

Inspection criteria (Ref. 1) recommend that a small-sized project with a high downstream hazard potential be capable of safely handling a flood in the range from one-half to the full probable maximum flood (PMF). Because of the downstream risk, the recommended spillway design flood for this project is one-half the full PMF. The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region. In Montana, east of the Continental Divide, the critical flood for reservoirs with drainage areas the size of the one for this project may result either from a generalized spring storm or from a severe thunderstorm during the late spring or summer.

During the dam safety analysis, an estimated PMF resulting from a 72-hour generalized storm was developed for the drainage basin. The resulting PMF has an estimated volume of approximately 2,112 acre-feet. The reservoir level at the beginning of the 72-hour storm was assumed to be at the spillway crest elevation.

Reservoir routings of the estimated 72-hour PMF indicate that the project will handle about 28% of the PMF volume before overtopping if the low-level outlet is fully closed. Or the project also will handle about 29.5% of the PMF volume before overtopping if the low-level outlet is fully open. The dam will probably erode and fail when overtopped by flood waters.

The upstream face of the dam shows considerable erosion by wave action where riprap coverage is inadequate above the high-water line. The riprap is generally in a deteriorated condition. The dam crest and the upstream and downstream faces show extensive burrowing by rodents. The downstream face shows damage from grazing animals, especially at the toe. In erodible materials, such as the clayey to sandy silt out of which the dam is built, animal damage and rodent burrows become considerable threats to the integrity of the dam.

Three previous failures (now repaired) in the downstream face of the dam, the apparent high phreatic surface, the relatively steep downstream slope, the seepage conditions at the downstream toe, and the clayey to sandy silt embankment materials indicate the safety factor against shear failure for the steady seepage condition is seriously less than the 1.5 required by the guidelines. With full pool conditions this dam is under an unacceptably high risk of failure.

On the basis of the field inspection and the study of hydrologic data, Higgins Brothers No. 1 Dam does not conform to Corps guidelines with respect to discharge and/or storage capacity to safely handle one-half the PMF. The observed deficiencies noted in the embankment are also of concern. This project is considered borderline unsafe, and immediate action is required to bring the project into acceptable condition.

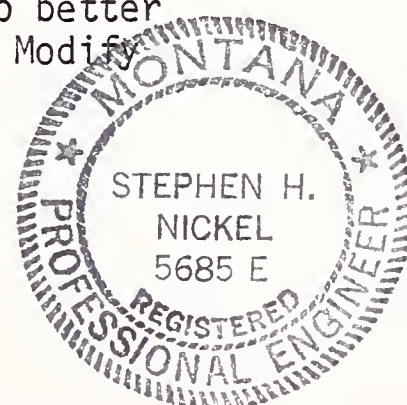
PRINCIPAL RECOMMENDATIONS

Due to the availability of storage between the normal pool and the dam crest, the present project provides a degree of flood protection to the downstream area. The intent of report recommendations is to maintain or improve project safety, if feasible, without decreasing this existing flood protection.

A downstream warning plan, for use in the event of possible embankment failure, needs to be developed and placed into operation immediately. A formal maintenance plan must be established.

Conduct engineering studies, including field investigations, piezometer installation, laboratory testing, and embankment seepage and stability analyses, to determine what embankment modifications are required for adequate stability.

Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity. Modify the project as studies indicate.



PERTINENT DATA

1. GENERAL

Federal ID No.	MT-30
Owner	Higgins Brothers, Inc.
Operator	James Higgins
Purpose	Irrigation, Stockwater
Location	Meagher County, Montana
Watershed	Tributary to Missouri River
Downstream Hazard Potential	Category I (High)
USGS Quadrangle	Hamen, Montana

2. RESERVOIR

Surface Area at Normal Pool	100 acres
Normal Storage (Spillway Crest)	408 acre-feet
Total Storage (Dam Crest)	860 acre-feet
Surcharge Storage	452 acre-feet
Drainage Area	2.0 square miles

3. SPILLWAY

Type	Uncontrolled earth and rock channel
Crest Elevation	5379.8 feet NGVD
Width	30 feet
Spillway Capacity (Dam Crest)	245 cfs

4. OUTLET WORKS

Type	Controlled corrugated metal pipe
Controls	Slide gate with manual control from dam crest
Length	70 feet
Size	15 inches diameter
Inlet Invert	5368.3 feet NGVD
Outlet Invert	5368.3 feet NGVD
Normal Tailwater	5368.5 feet NGVD (estimated)
Discharge Capacity at Dam Crest	14 cfs (approximately)

5. DAM

Type	Earth
Maximum Height	14.6 feet
Crest Length	900 feet
Crest Elevation	5382.9 feet NGVD
Crest Width	18.5 feet
Upstream Slope	1(V) to 1.8(H) (Average)
Downstream Slope	1(V) to 1.7(H) (Average)

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of the Higgins Brothers No. 1 Dam, owned by Higgins Brothers, Inc., of Ringling, Montana.

The National Dam Inspection Act, Public Law 92-367 dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers to conduct safety inspections of non-federal dams throughout the United States. Pursuant to that authority, the Office of the Chief of Engineers issued "Recommend Guidelines for Safety Inspection of Dams" (Ref. 1) in May, 1975.

The recommended guidelines were prepared with the help of engineers and scientists, highly experienced in dam safety, from many federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community:

Where necessary, the guidelines outline a two-phased study procedure for investigating and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

- (1) a limited investigation to assess the general safety condition of the dam.
- (2) based upon an evaluation of the available data and a visual inspection.
- (3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted.
- (4) not intended to include extensive explorations, analysis or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies but only to the extent needed to answer

serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase 1 recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and neither action nor failure to act under this Act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected in a timely manner by non-Federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based on a 10 May 1979 visual inspection of the project, a brief engineering analysis, and an interview with the owner. No design drawings or foundation exploration results were available for review or analysis. Inspection procedures and criteria were those established by the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1).

Personnel present during the inspection included:

Louis Boitano, Civil Engineer, Seattle District Corps of Engineers
Lawrence Tegg, State of Montana, Department of Natural Resources
and Conservation
James Higgins, Higgins Brothers, Inc., Owner

Hoskins-Western-Sonderegger, Inc. (HWS) personnel who participated in the field inspection and contributed to this report are:

Stephen Nickel, Geotechnical Engineer, Team Leader
Richard Walker, Hydrologist/Hydraulics Engineer

1.2 DESCRIPTION OF PROJECT

1.2.1 General

Higgins Brothers No. 1 Dam (MT-30), owned by Higgins Brothers, Inc., forms an off-channel irrigation and stockwater storage impoundment for water diverted from Woodson Creek. The dam is located in Section 9, T6N, R8E,

Meagher County, Montana, approximately 3.5 miles northeast of Ringling. The dam has a drainage area of 1260 acres, a surface area of approximately 134 acres and a storage of about 408 acre-feet at the spillway crest elevation of 5379.8 feet, and a maximum storage of about 860 acre-feet at the minimum dam crest elevation of 5382.9 feet. The spillway, located at the right dam abutment, is an uncontrolled earth and rock channel, generally 30 feet wide. A 15-inch-diameter corrugated metal pipe, with an inclined-stem slide gate operated from the dam crest, make up the irrigation outlet works for the dam. As Higgins Brothers No. 1 Dam is approximately 15 feet high and impounds approximately 860 acre-feet at the minimum dam crest elevation, it is classified as being of small size. Based upon visual reconnaissance and engineering judgment, the town of Ringling, the Higgins ranch, Highway U.S. 89, and the C. M. St. P. & P. Railroad could be affected by a sudden breach of the dam. Higgins Brothers No. 1 Dam, therefore, has a high (Category I) downstream hazard potential classification (Ref. 1).

1.2.2 Regional Geology

The drainage area of Sixteenmile Creek is a region of basin and range complicated by thrust faulting. Geographically, the Castle Mountains, to the north of Sixteenmile Creek, is at the center of a group of basins which radiate roughly north, east, south, and west, with the small basin which forms the Sixteenmile Creek valley trending westward. The Castle Mountains and the Big Belt Mountains are north of Sixteenmile Creek, the Crazy Mountains are on the east, and the Bridger Range is on the south.

Before the late Cretaceous, this was an area of quiet basinal sedimentation. Pre-Cambrian, Paleozoic, and Mesozoic sedimentation produced sandstones and shales. These Pre-Cambrian and Lower and Middle Paleozoic sedimentary and metamorphic rocks are exposed in the mountains and are only exposed due to the mountain-building that occurred.

During late Cretaceous times and Tertiary times, three possible phases of mountain building seem to have occurred: (1) initial Cretaceous uplift of the Central Montana arch; (2) late Cretaceous thrust faulting (as evident west of the White Sulphur Springs area) which produced attendant normal and high-angle reverse faulting, with fracture faulting also common; and (3) Tertiary igneous activity which involved the formation of the Castle and Crazy Mountains. The igneous rocks are alkalic and are composed of syenites and other alkalic-rich varieties. With the intrusion of these igneous bodies and the thrust faulting, the older Pre-Cambrian and Paleozoic rocks were uplifted and exposed, as in the case of the Big Belt Mountains. The attendant foothills of the ranges are of later Paleozoic and Lower Mesozoic sediments.

During this mountain-building phase, the basinal sediments where the Sixteenmile Creek now runs were folded into a series of anticlines and synclines. Subsequent to the mountain building came erosion. Erosional debris from the mountains, primarily volcanic material from the Crazy

Mountains, swept down by rivers and streams, covered the earlier Cretaceous sandstones and shales and formed the Livingston Formation, consisting of agglomerate, conglomerate, sandstone, and shale. Subsequent erosion of much of these younger sedimentary rocks, along with the tops of the anticlines, has produced the present topography which shows steeply-dipping ridges of Cretaceous and older rock, while younger Cretaceous and Tertiary rock fills the synclines. The Cretaceous deposits are predominantly the Eagle Sandstone, the Colorado Shale, and the younger Livingston Formation. Later Tertiary gravels and sands form the low terraces of Sixteenmile Creek, with Pleistocene alluvium along the recent bed of the stream.

1.2.3 Seismicity

The reservoir and dam lie in Seismic Zone 3, as indicated by the Seismic Zone Map (Ref. 1). The seismic probability of Zone 3 is one of a potential for major damage and is based on the known distribution of damaging earthquakes in the region. The Geologic Map of Montana shows several faults 5 to 10 miles from the dam to the west, northwest, north and northeast. These are the closest known faults.

Epicenters of local earthquakes of sufficient magnitude or intensity to be reported in Reference 13 and 14 have occurred approximately along a line from 20 miles northwest of Helena to 25 miles north of Bozeman. The 3 largest reported earthquakes along this line have had intensities of VIII (Modified Mercalli). One of these earthquakes had its epicenter at a point roughly 25 miles north of Bozeman (27 June 1925), while the other two occurred at Helena (18 October and 31 October 1935). Of these two epicentral areas, the former is 30 and the latter is 85 miles from the dam.

1.2.4 Site Geology

Higgins Brothers No. 1 Reservoir lies in a syncline in an outcrop area of the Livingston Formation. The reservoir lies about a mile west of the synclinal axis. The north-south trending ridges both east and west of the reservoir are surface expressions of the syncline. The ridges west of the reservoir can be seen in Photo 1. Dip, as observed in the spillway channel is greater than 45 degrees (see Photo 10).

The site is at the edge of the valley cut by Woodson Creek and Sixteenmile Creek. Along the dam center line, the thickness of alluvium over bedrock appears to vary from zero at the right abutment to about 8 feet at the diversion inlet in the left abutment. The alluvium consists of clayey to sandy silt with some gravel and cobbles. According to the owner, there is probably no cutoff. No borings are known to have been made.

1.2.5 Design and Construction History

At the time of the inspection, James Higgins stated that the dam was built in 1936 by his father with SCS assistance. No plans or other construction records are available.

Three rockfill areas on the downstream slope apparently indicate where slope failures have been repaired. These areas can be seen on Photo 9. The repair work does not appear to be recent.

CHAPTER 2

INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillway

An excavated earth and rock channel which functions as spillway, is located at the right (north) abutment of the Higgins dam. Erosion at a rock outcrop area, located approximately 40 feet from the edge of the reservoir at normal pool elevation, is the main evidence of damage to the channel from periodic usage. Further erosion of the spillway at the rock outcrop may occur during periods when the spillway is used, however, this erosion will probably be minimal and poses no threat to the integrity of the dam. Photographs 10 and 11 show the emergency spillway and rock outcrop area. Approximate dimensions and elevations were determined in the field for use in the calculation of the discharge capacity of the spillway channel.

The 40-foot-long approach channel is fairly uniform in both slope and cross section and is clear of any heavy or dense growth. The control section for the spillway is at the rock outcrop. The gully downstream from the rock outcrop meanders in a southwesterly direction and empties into Sixteenmile Creek a few hundred yards downstream (see Plate 4 for the spillway configuration). The discharge rating for the spillway was computed by assuming critical depth occurs at the control section and computing water surface profiles upstream into the reservoir using a Manning's roughness coefficient of 0.035. The discharge of the spillway at elevation 5382.9, which is the approximate low point on the dam, is about 245 cfs. The spillway rating curve is given on Plate 7.

2.1.2 Outlet

The low-level gravity outlet through the dam is a 15-inch diameter corrugated metal pipe (CMP) with a slide gate on the upstream end to control the rate of flow through the pipe (Photo 6). The length of the outlet pipe is approximately 70 feet. A sketch of the dam cross section at Station 5+00, which includes the outlet pipe, is shown on Plate 3. The pipe outlet invert is 14.6 feet below the crest of the dam and 11.5 feet below the minimum spillway crest elevation. A visual inspection of the upstream end of the outlet pipe was not possible due to the elevation of the reservoir; however, the inspection of the downstream end revealed that approximately 1.5 feet of the CMP had been broken off the end, leaving a jagged edge which is rusting (see Photo 7). The outlet pipe discharge rating curve (Plate 8) was computed assuming full pipe flow discharge, with no tailwater restrictions and the slide gate completely raised. The discharge capacity of the 15-inch CMP outlet is about 12 cfs when the reservoir is at the crest of the spillway and approximately 14 cfs at the minimum crest elevation of the dam.

The presence of salt deposits on the downstream face, presumably deposited by seepage water, indicates the potential for galvanic corrosion of the metal conduit. The condition of the conduit needs to be checked regularly so that it can be repaired or replaced before rust perforation leads to a piping failure of the embankment.

2.1.3 Diversion Canal

One of the major sources of inflow for Higgins Reservoir is a diversion canal which is fed by waters collected beyond the natural drainage area of the reservoir, via Woodson Creek. The control to the canal is a 30-inch-diameter CMP located a few hundred feet upstream from where the canal enters the reservoir (see Photo 3). The maximum hydraulic inflow capacity of the CMP was calculated to be 20 cfs.

2.1.4 Freeboard

The fetch for wind-generated waves is about 2000 feet and the wave run-up and set-up on the embankment is estimated to be 3 feet. At the spillway crest elevation of 5379.8 feet, an approximate 3-foot-difference exists to the dam crest and is considered very marginal in preventing wave overtopping. Routings indicate that dam overtopping occurs during one-half PMF conditions, therefore, no freeboard exists during the recommended spillway design flood.

2.2 HYDROLOGY, CLIMATOLOGY, AND PHYSIOGRAPHY

2.2.1 Physiography and Climatology

The climate of the area around Higgins Reservoir is highly variable, having great temperature extremes and is most generally characterized as continental. The effects of foehn or chinook winds, which are westerly or southwesterly and Pacific Maritime in origin, are important in determining the extreme precipitation and runoff conditions which occur in this area. The summers are warm with cool nights and low humidity, while winters are moderately cold and highly variable in severity.

White Sulphur Springs, located 19 miles north northwest in the Smith River Valley at 5100 feet elevation, is the nearest climatological station which is considered representative of the damsite. Climatological data is available for 70 years, and the mean annual precipitation at White Sulphur Springs is about 18 inches. Temperature extremes at White Sulphur Springs are -50° F and 105° F. The average expected date of the last freeze is June 19th and the average first freeze date is August 28th (Reference 8).

The drainage basin, which extends north, east and west of the reservoir, is approximately trapezoidal in shape, and encompasses an area of about 2.0 square miles. The basin elevations range from the normal pool elevation of 5379.0 to approximately 5545 along the western side of the basin.

The ground slopes vary from approximately 25 feet in one mile to the north, to a maximum of over 250 feet per mile to the west. The Crazy Mountains and Castle Mountains lie east and north of the reservoir, respectively.

Historic flood flows for the general area have been documented and recorded. The Shields River Basin, located 15 miles southeast, has had a flood of record of 20.2 cfs per square mile on 88 square miles. And the North Fork of the Musselshell River, located 22 miles northeast has had a flood of record of 13.5 cfs per square mile on 31.4 square miles (Reference 4).

2.2.2 Probable Maximum Flood (PMF)

The probable maximum flood (PMF) is defined as the flood expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. In Montana, east of the Continental Divide, the critical flood for a given reservoir may either result from a generalized spring storm or from a severe local thunderstorm during late spring or summer. A storm, the intensity of which approached probable maximum precipitation (PMP) intensity, did occur in Montana in 1964 near the basin.

A PMP, 72-hour duration storm was applied to the basin. This storm was derived in the following manner: the 24-hour index, 12-hour, 6-hour and 1-hour depths were estimated from the National Weather Service Technical Paper No. 38 (Ref. 6), and the 48- and 72-hour PMP depths were taken as 110% and 115% of the 24-hour index PMP, respectively. All 6-hour increments from 0 to 72 hours were arranged in a critical order of occurrence.

The PMF was assumed to result from a PMP storm in late spring over hard and frozen ground. Thus, a constant soil loss rate of 0 was applied throughout the 24-hour PMP storm, in accordance with Corps of Engineers recommendations. Therefore, the overall configuration of the 24-hour storm is not affected by losses in the soil, and basin rainfall is equal to basin runoff for all storm increments. Direct precipitation onto the surface of the lake was also added in with no losses.

2.2.3 Reservoir Stage and Spillway Discharge

The reservoir has a surface area of about 134 acres and a storage of 408 acre feet at the assumed minimum spillway crest elevation of 5379.8 feet NGVD. Approximately 456 acre-feet of storage are available between this spillway crest and the minimum crest elevation of the dam. The discharge of the spillway at the minimum crest of the dam is about 245 cfs. This discharge would increase an additional 14 cfs if the low-level outlet were fully opened.

2.2.4 Flood Routing

The water level of Higgins Reservoir at the beginning of the 72-hour PMP storm was assumed to be at the spillway crest elevation of 5379.8 feet.

The total volume of the 72-hour PMF for Higgins Reservoir is approximately 2,112 acre-feet, with the peak inflow rate of 10,488 cfs occurring during the 41st hour of the storm. Reservoir routings indicate that, with the control gate of the irrigation outlet closed, the project will safely handle, through storage and spillway discharge, approximately 28% of the PMF volume before overtopping. With the control gate of the irrigation outlet fully open, the project also will safely handle approximately 29.5% of the PMF volume before overtopping.

PMF hydrographs were developed using the SCS dimensionless unit hydrograph. Reservoir routings of the inflow hydrographs were made using the Modified Puls method. The HEC-1 (Dam Safety Version) computer program was used for the hydrograph computations and reservoir routings (Reference 11).

2.3 GEOTECHNICAL EVALUATION

2.3.1 Dam Embankment

The 14.6-foot-high dam has a crest width of 18.5 feet and a crest length of about 900 feet. The upstream slope is generally 1(V) to 1.8(H), while the downstream slope is 1(V) to 1.7(H). The crest is fairly uniform, varying about 1 foot in elevation. Numerous rodent burrows were visible on the crest and on the upstream and downstream faces of the dam.

The embankment material is clayey to sandy silt and appears to be quite susceptible to erosion. During an overtopping event, erosion would apparently lead rapidly to a breaching failure. Wave action seems to have eroded the upper 2 to 3 feet of the upstream face, removed the riprap from this area, and deposited the riprap near the permanent pool elevation. The riprap is primarily sandstone and is deteriorating.

Vegetation occurs only on the crest and the downstream face. The crest is covered with grass, while the downstream face has 50% coverage of grass and sagebrush.

Failure of the downstream embankment slope appears to have occurred in at least 3 locations, with subsequent repair using rockfill. These areas are shown on Photo 9.

2.3.2 Foundation Conditions, Seepage, and Drainage

Foundation conditions beneath the dam are unknown, however, foundation materials exposed nearby consist of alluvial silts, gravels, and cobbles, similar to the embankment material, overlying bedrock at a shallow depth. The thickness of the alluvium seems to vary from nearly zero at the right abutment to about 8 feet at the left abutment.

The alluvial foundation materials appear to be quite permeable in their natural state and only slightly less so when compacted as embankment.

According to the owner, the dam embankment contains no internal drainage system. Lack of internal drainage is also indicated by seepage or the vegetative evidence of seepage along almost the entire length of the dam, on the lower part of the downstream slope, and below the downstream toe. The seepage evidence consisted of greener grass, higher susceptibility to animal damage than the remainder of the embankment, and the presence of salt deposits on the slope surface. This evidence of seepage was found up to 7 feet, vertically, above the toe. The soil near the toe was very wet to saturated, and although no concentrated seeps were found, water was standing between the clumps of grass below the toe and was moving into the exit channel. The water was clear.

At the time of the inspection, water was flowing out of the outlet conduit. Whether this water was leaking past the slide gate (which was closed) or was seepage water entering the conduit through cracks or holes could not be determined. However, this water was also clear, indicating that no internal erosion is occurring.

2.3.3 Stability

The quantity of seepage did not appear to be large, even with the pool elevation within 1 foot of the spillway at the time of the inspection. However, the fact that seepage occurs for nearly the entire length of the dam (up to 7 feet vertically above the toe), that the downstream slope is steep and that the downstream slope appears to have had failures in at least three locations are cause for concern about the stability of the dam. A stability analysis was not available for review; however, the safety factor for the condition of steady state seepage from the maximum pool appears to be only slightly more than 1.0. The soil type and seepage forces combine to make the existing conditions at the toe potentially dangerous, requiring immediate detailed investigation, analysis, and remedy. Inspection guidelines require a safety factor of at least 1.5 for the steady seepage condition with full pool. Therefore, in our opinion, the dam does not conform to guidelines with respect to stability. Additionally, the presence of rodent burrows may affect the stability by leading to failure by piping.

2.4 PROJECT OPERATION AND MAINTENANCE

2.4.1 Dam

There is no formal plan for performing periodic maintenance of Higgins Brothers No. 1 Dam. Maintenance appears to be performed on a piecemeal basis. The most notable present need for maintenance is in the areas of providing additional, adequate, upstream slope protection (riprap) and correcting damage from burrowing animals, damage from cattle, and damage to the conduit.

Riprap coverage on the upper 2 to 3 feet of the upstream embankment face is inadequate and considerable erosion of the crest has occurred (see Photos 5 and 6). The riprap appears to be sandstone, some of which is deteriorating.

The embankment crest and the upstream and downstream faces show numerous rodent burrows. As rodent burrows can lead to piping failures, rodent control should be a part of any formal maintenance plan.

The lower 3 to 7 feet of the downstream face (measured vertically) shows extensive damage from cattle. This is the area where soil moisture and salt deposits indicate a seepage surface. In many places the embankment toe has been destroyed, leaving a much steeper slope for the lower 3 to 7 feet. Such changes in embankment cross section lower the safety factors against shear failure and against piping failure.

2.4.2 Reservoir

At the time of the inspection the reservoir level was within 1 foot of the spillway elevation. The reservoir level fluctuates seasonally, being low in winter, full by the start of the irrigation season, and low again by autumn. Inflow is through a diversion canal from Woodson Creek. The outlet is controlled by a gate valve for the release of irrigation water. There is slight erosion of the shore of the reservoir right of the right abutment (see Photo 4). However, no remedial action is needed.

2.4.3 Warning System

There is no formal warning system or plan of action to warn downstream inhabitants in the event of impending dam failure.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the Higgins Brothers No. 1 Dam and Reservoir, supplemented by analysis of the project in terms of the recommended guidelines' performance standards, resulted in the following findings.

3.1.1 Size and Hazard Classification and Safety Evaluation

In accordance with inspection guidelines, Higgins Brothers No. 1 Dam is classified as small in size with a high downstream hazard potential rating. The recommended spillway design flood (SDF) for this project is in the range of from one-half to the full probable maximum flood (PMF). Because of high downstream risk, the project should be able to handle one-half the PMF. As the project can safely handle only 28% of the PMF without overtopping, leading to embankment failure by breaching, Higgins Brothers No. 1 Dam does not meet inspection guidelines. Also, the observed embankment deficiencies are of concern, and the project is considered borderline unsafe until recommended actions are accomplished.

3.1.2 Embankment Dam

Three rockfill areas exist in the downstream face of the dam. These appear to be repaired slope failures. The cross section of the lower 3 to 7 feet of the downstream face has been considerably altered and oversteepened by the action of animals. In addition, evidence of high phreatic surface on the downstream slope occurs for most of the length of the dam. Based on experience with similar structures, materials, and conditions, the stability of the downstream embankment slope does not conform to the recommended guidelines.

Riprap coverage on the upstream face appears to be adequate except for the upper 2 to 3 feet. Some erosion of the crest has occurred due to inadequate protection on the upper 2 to 3 feet of the upstream slope. The riprap is degradable sandstone.

Rodent burrows were visible on the embankment crest and the upstream and downstream faces. Rodent burrows are especially dangerous in dams like Higgins Brothers No. 1, where the embankment material contains very little clay and is therefore susceptible to erosion and piping.

3.1.3 Outlet Works

Higgins Reservoir has one 15-inch CMP low-level outlet, with a manually controlled slide gate. The maximum discharge capacity, with the slide gate completely raised is estimated to be about 14 cfs. The downstream end of the outlet has been broken off, and the pipe may be subject to corrosion damage.

3.1.4 Spillway and Reservoir Capacity

The spillway is an uncontrolled earth and rock channel in the right abutment. The crest of the spillway is 3.1 feet below the crest of the dam. The maximum capacity of the spillway is about 260 cfs with the pool at the approximate dam crest elevation of 5382.9 feet NGVD.

The flood resulting from the PMP storm of 72 hours duration for the 2.0-square-mile drainage area, including the reservoir, is estimated to have a volume of 2112 acre-feet. The combination of reservoir surcharge storage and spillway and outlet pipe discharges is insufficient to prevent overtopping of the dam during one-half the PMF.

3.1.5 Operation and Maintenance

Operation and maintenance are performed by Mr. Higgins or his employees. The site is visited only when necessary. Water is diverted from Woodson Creek and is released from the low-level outlet as needed for irrigation. As a consequence, the reservoir level fluctuates seasonally.

Maintenance of the dam is not adequate as evidenced by the condition of the conduit, inadequate riprap coverage on the upper portion of the upstream face, rodent burrows, and animal damage at the downstream toe.

There is no formal warning system or plan of action to alert downstream inhabitants in the event of dam failure.

3.2 RECOMMENDATIONS

1. Immediately develop and implement and periodically test an emergency warning plan for use in the event of dam overtopping or impending failure by other means.
2. Inspect the low-level outlet conduit and repair if required. Provide adequate embankment protection around the exit of the conduit.
3. Accomplish repairs on both the upstream and downstream embankment faces to bring the cross section back to original design. Place additional, adequately-designed riprap on the upstream face of embankment where existing coverage is inadequate. In addition, eliminate rodent populations and repair rodent damage.
4. Establish and carry out a program of regular maintenance to continue the measures stated in Recommendations 1, 2, and 3.
5. Conduct and place on file, stability and seepage analyses of the dam embankment. We recommend these analyses be performed by a qualified geotechnical engineer and be based on: seismic and static loading conditions; in situ strength properties of the embankment, foundation and abutment materials; and phreatic surface conditions. Determine the seismic loads based on a seismic assessment

of the area, and also evaluate the project's response to a seismic event. Establish the material strength properties by drilling and sampling with laboratory testing as appropriate, and obtain the phreatic surface by installing and monitoring piezometers.

6. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity.
7. Modify the project as studies indicate.
8. Conduct periodic comprehensive inspections at no more than 5-year intervals. These inspections should be performed by engineers with experience in dam design and construction.

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14. U.S. Geological Survey, "Earthquake Information Bulletin," Washington, D.C., 1973-1978.



(PHOTO 1) Overview, Higgins Brothers No. 1 Dam and Reservoir.



(PHOTO 2) Upstream face of dam from left side of reservoir.



(PHOTO 3) Diversion inlet at left abutment.



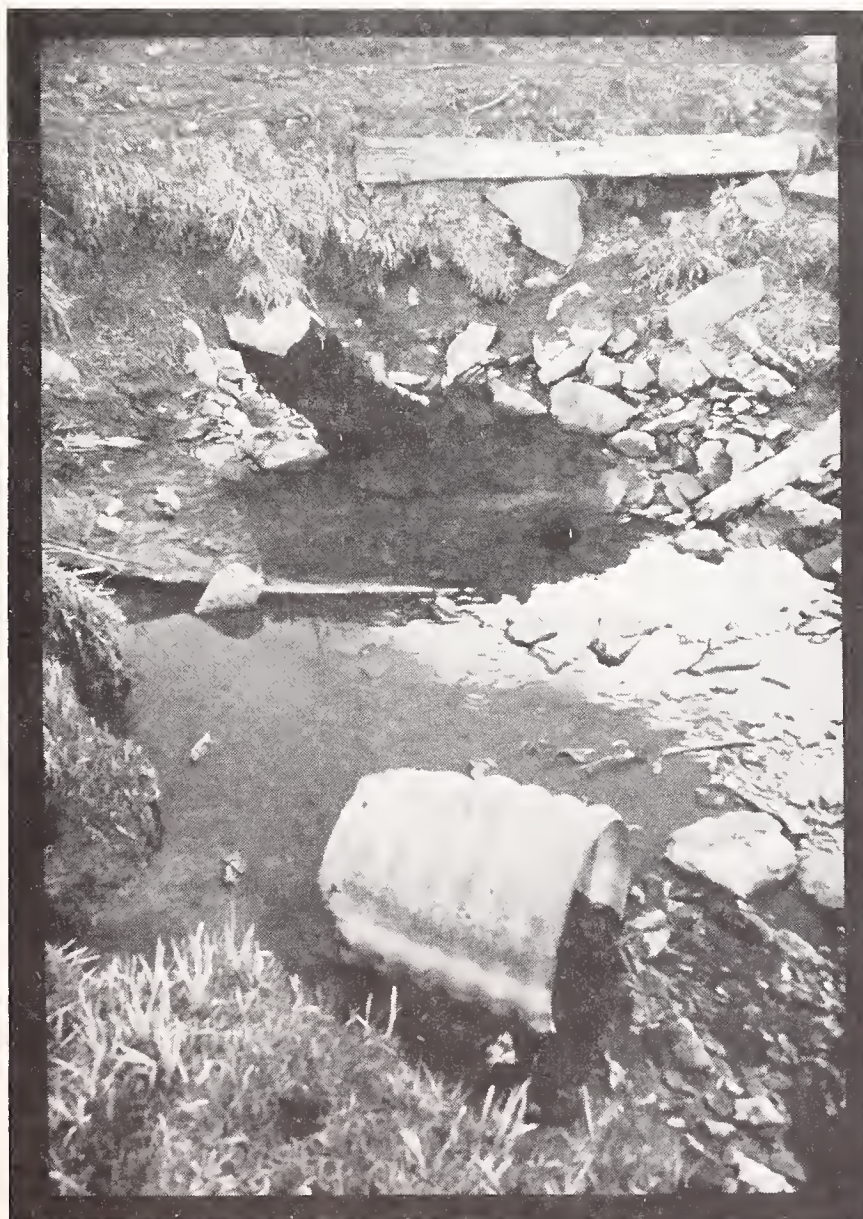
(PHOTO 4) Erosion on right slope of reservoir.



(PHOTO 5) Riprap on upstream face.



(PHOTO 6) Control works for low-level outlet.



(PHOTO 7) Broken conduit outlet.



(PHOTO 8) Looking downstream from west of dam at conduit location.



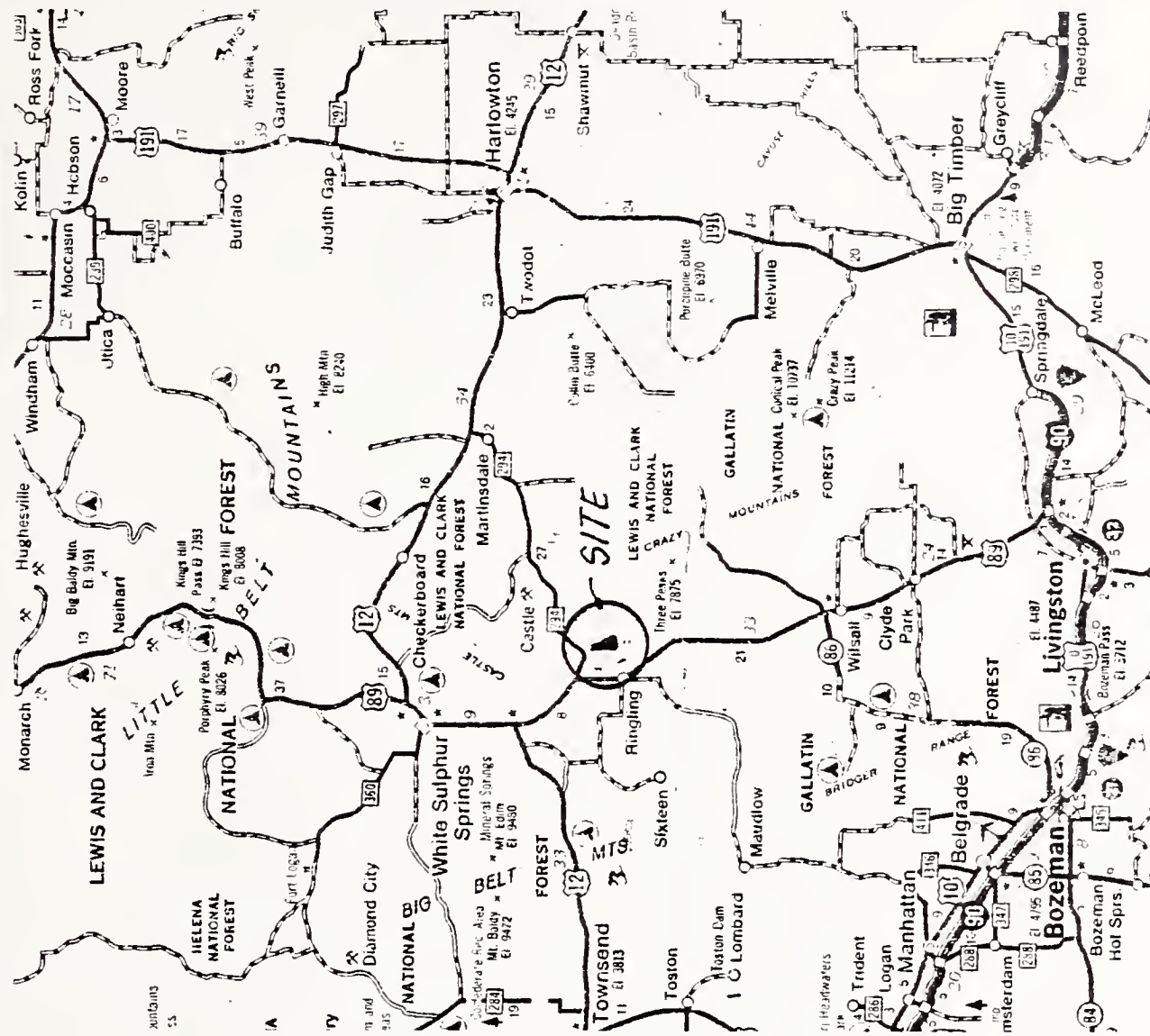
(PHOTO 9) Downstream face of dam.



(PHOTO 10) Looking upstream in excavated spillway channel. Rock outcrop (spillway control) in foreground.

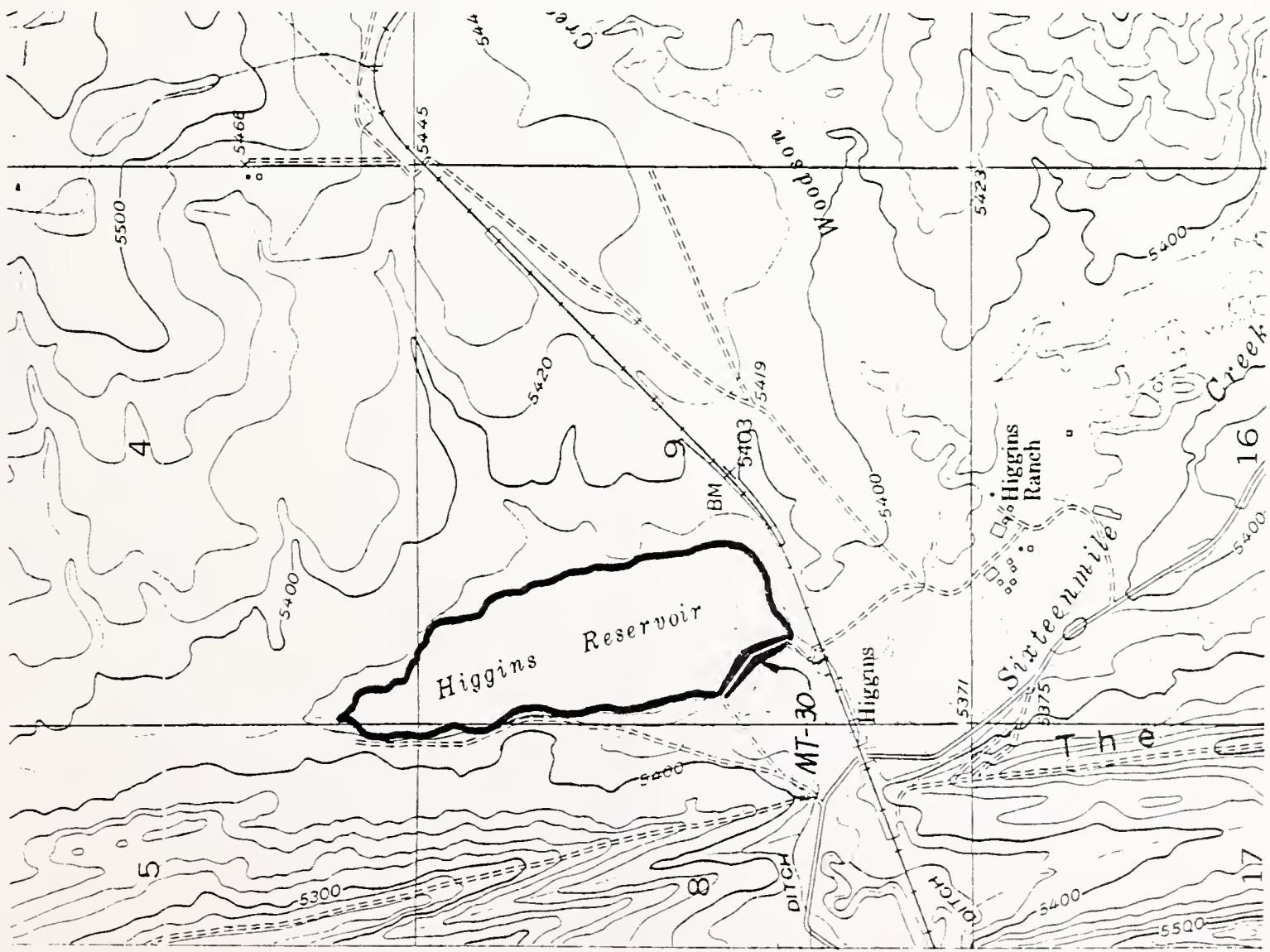


(PHOTO 11) Looking downstream in excavated spillway channel.



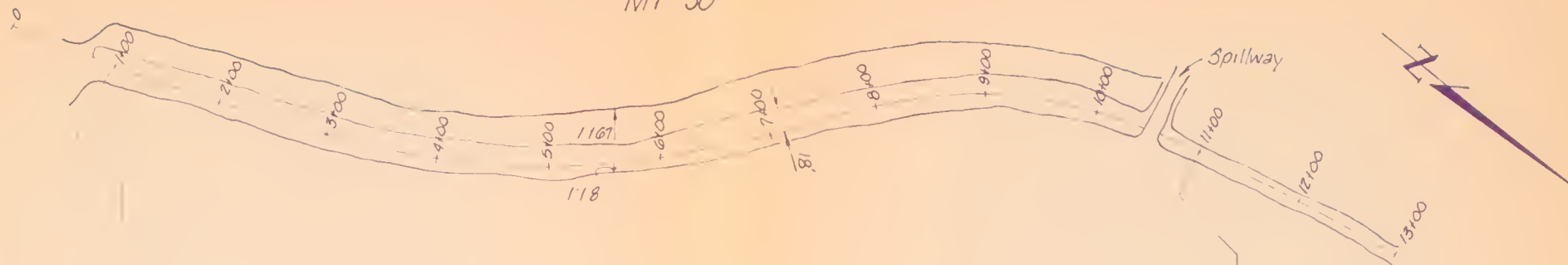
VICINITY MAP

HIGGINS BROTHERS NO. 1 DAM AND RESERVOIR SITE PLAN & VICINITY MAP

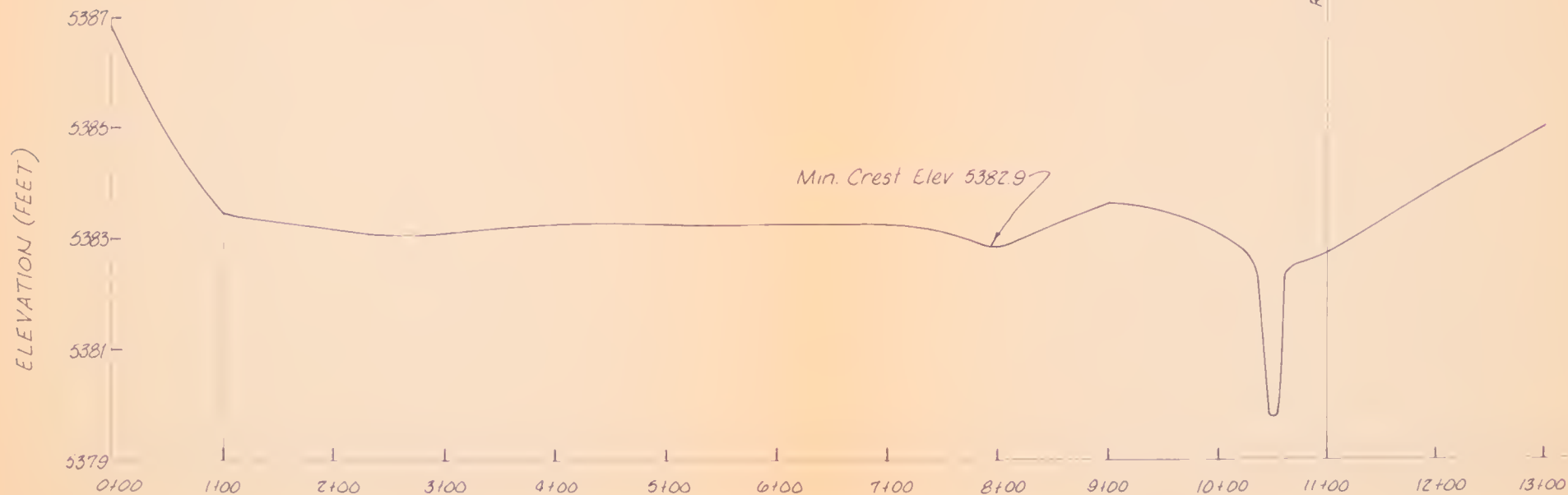


SITE PLAN

HIGGINS BROTHERS No. 1 DAM M7 30

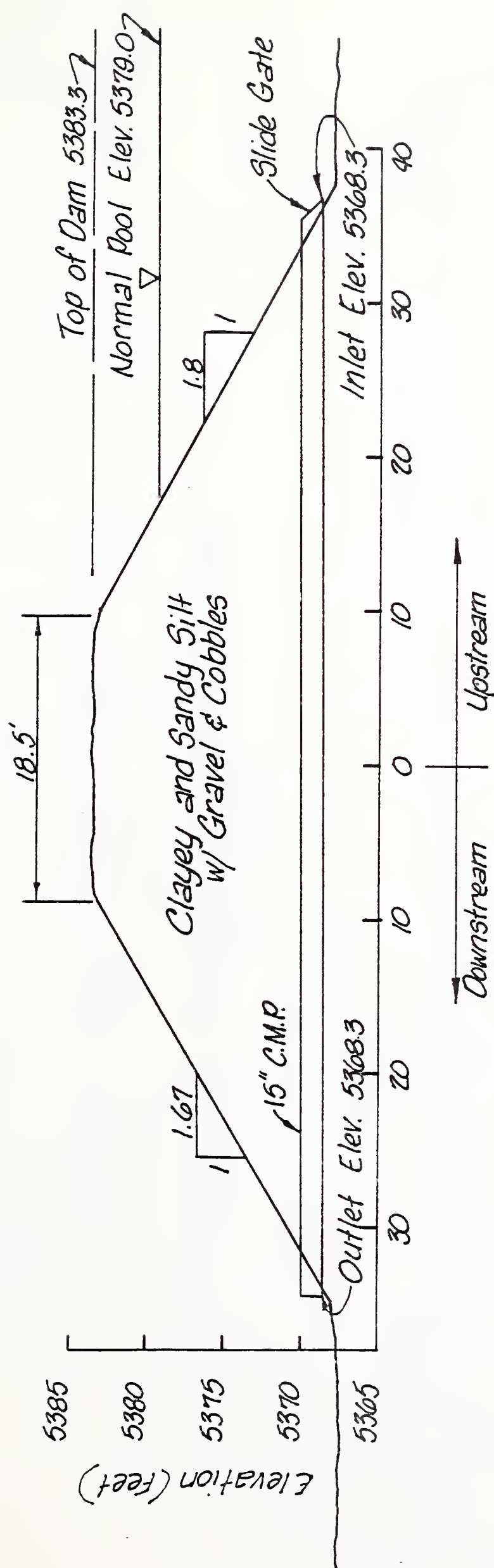


PLAN OF DAM



CENTERLINE PROFILE HIGGINS DAM

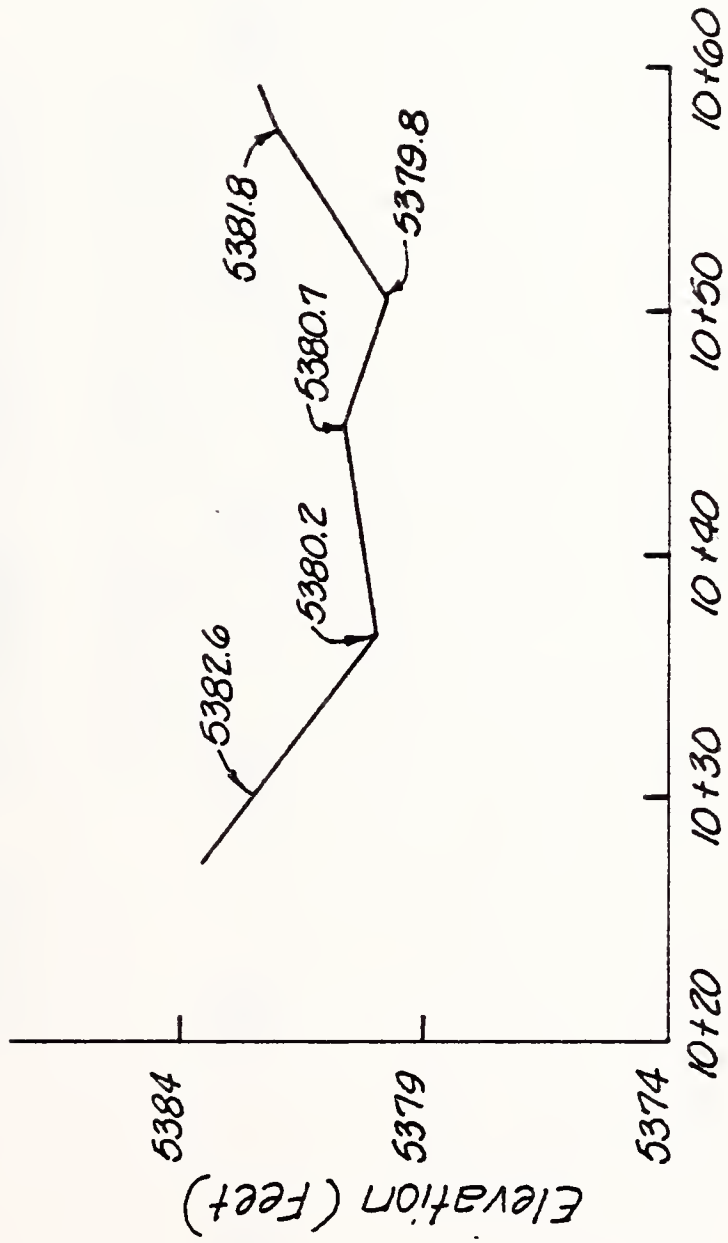
Scale: 1" = 100' H
1" = 2' V.



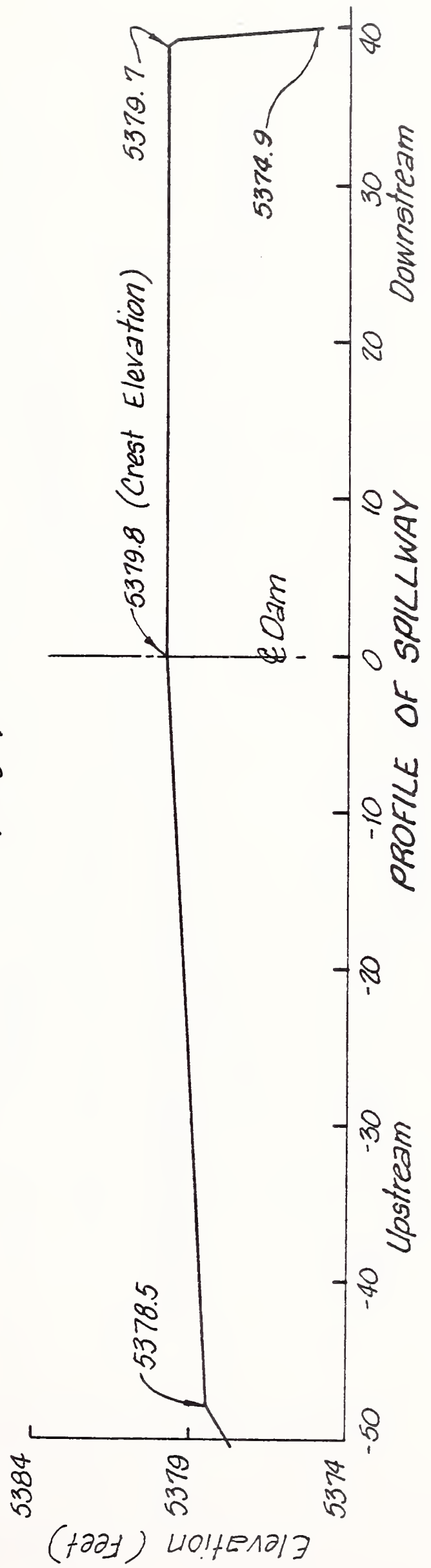
CROSS SECTION HIGGINS BROTHERS No. 1 DAM
INCLUDING OUTLET PIPE STATION 5+00

Scale: 1" = 10'

HIGGINS BROTHERS NO. 1 DAM

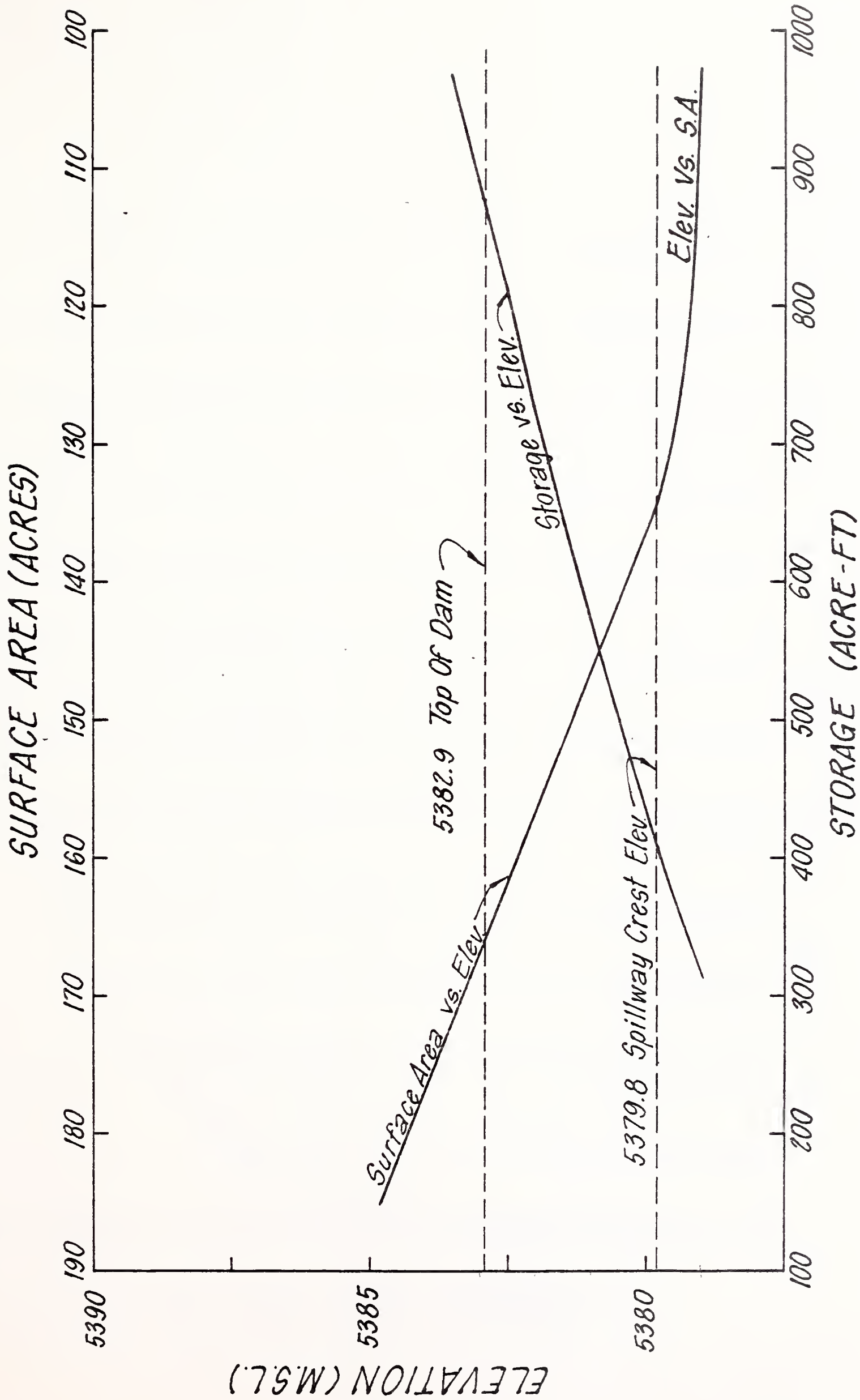


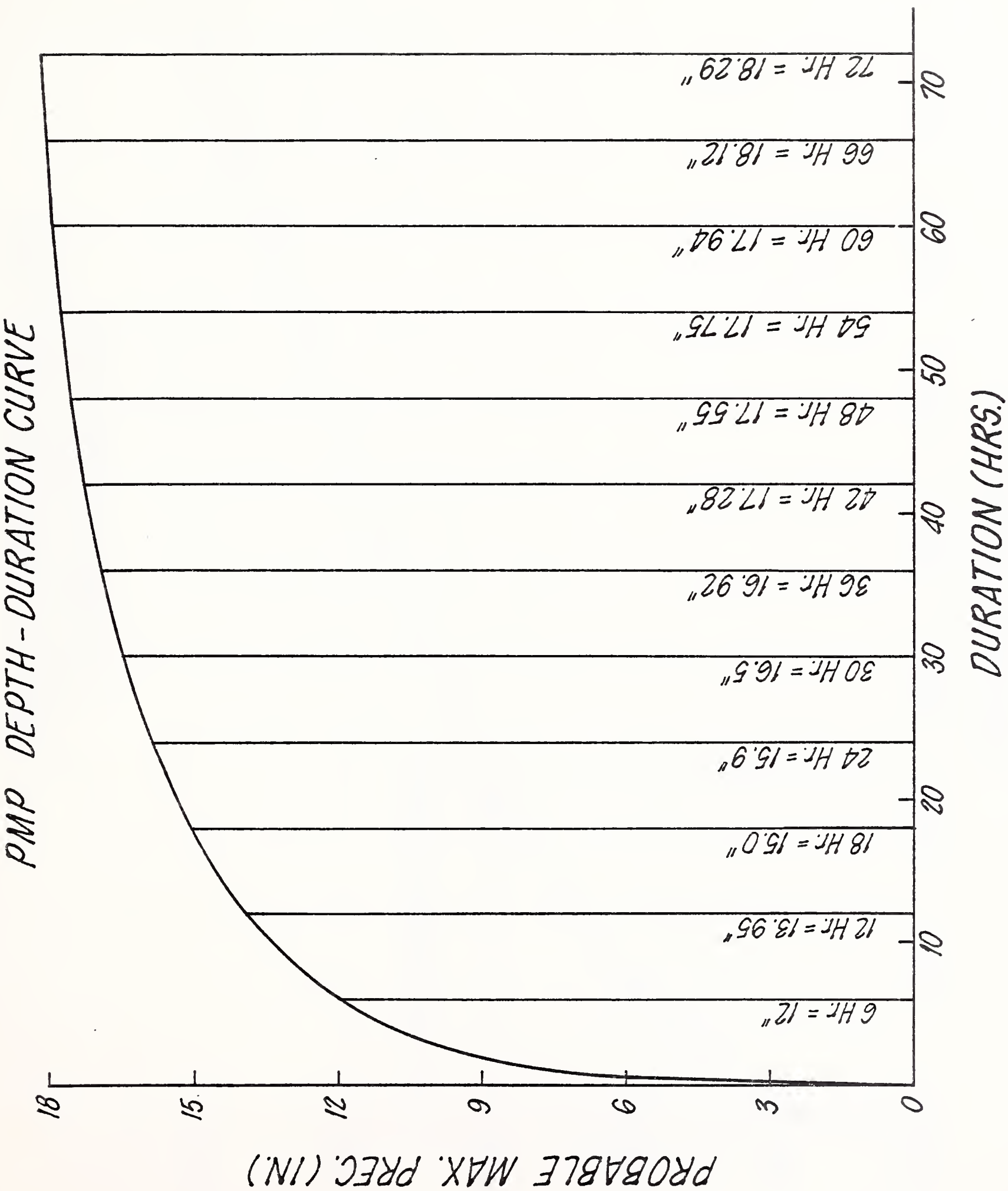
SPILLWAY SECTION AT DAM CENTERLINE
Scale: 1" = 10' H.
1" = 5' V.



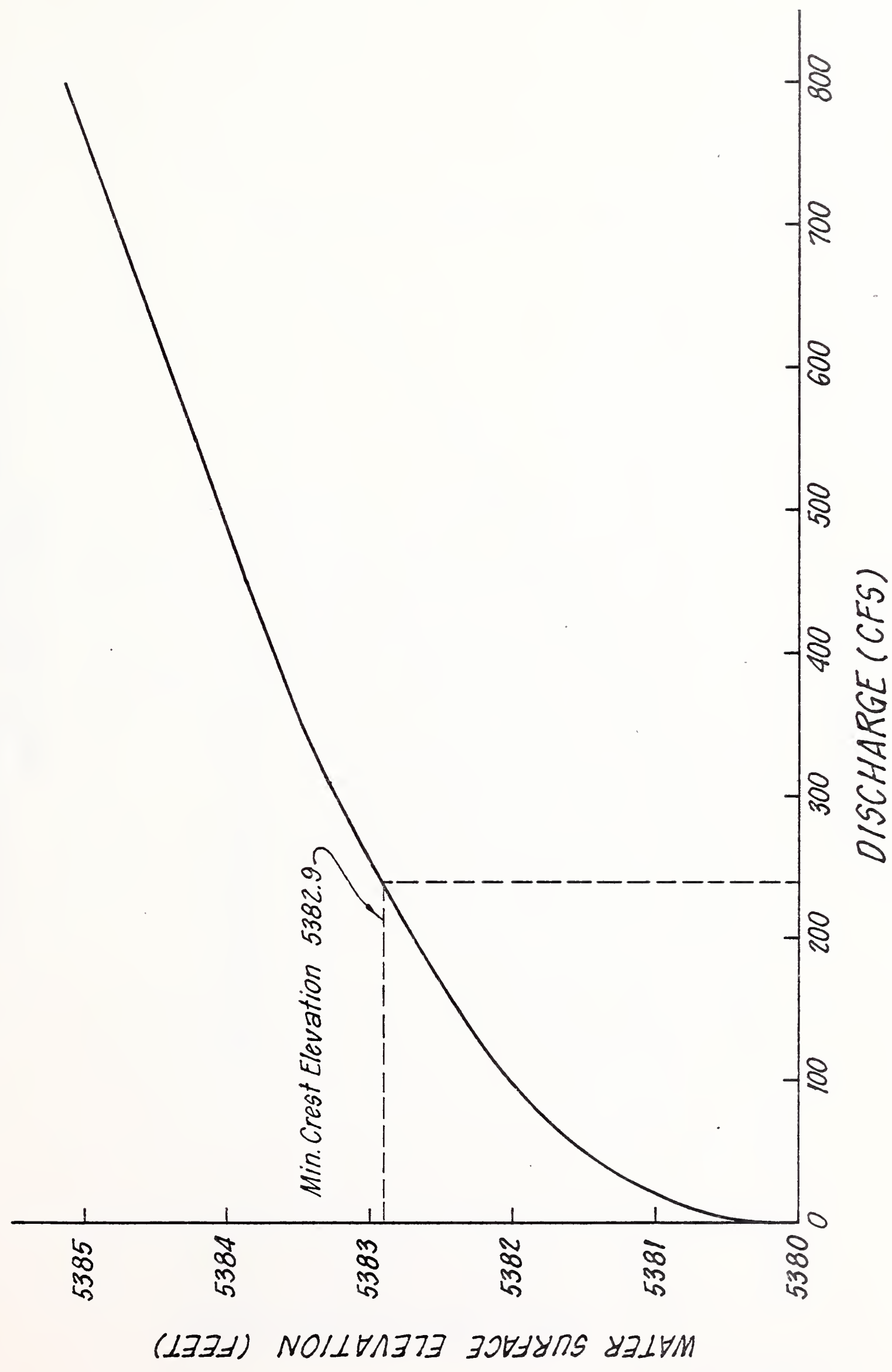
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HIGGINS BROTHERS No.1 DAM
STAGE - STORAGE - AREA CURVE

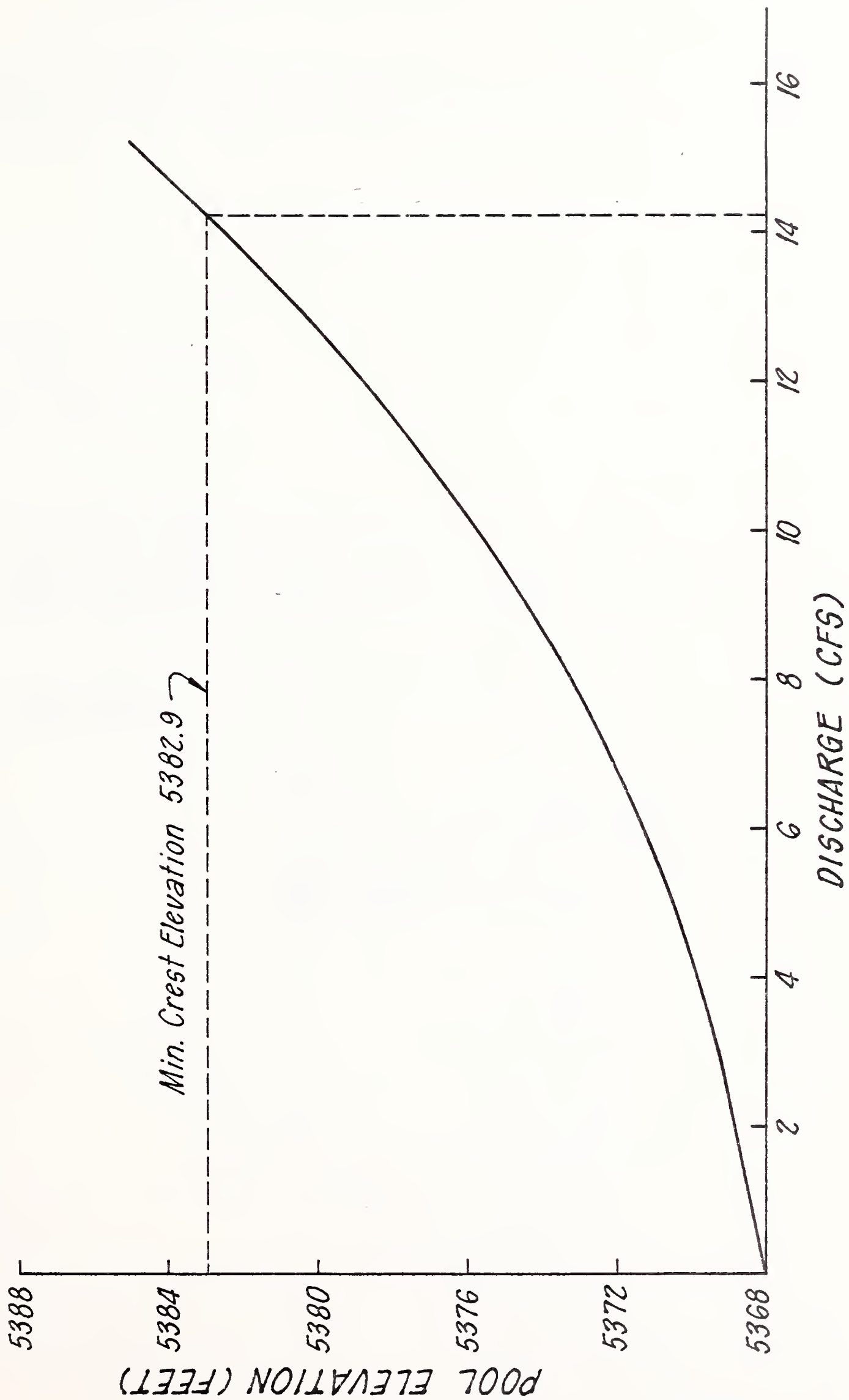




HIGGINS BROTHERS NO. 1 DAM
SPILLWAY RATING CURVE



HIGGINS BROTHERS No.1 DAM
15" C.M.P. Outlet Discharge Rating Curve
GATE FULLY OPEN



DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION



THOMAS L. JUDGE, GOVERNOR

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HELENA, MONTANA 59601

June 20, 1980

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Ralph:

The Department of Natural Resources and Conservation has reviewed the final draft report on the Higgins Bros. No. 1 Dam (MT-30). We concur with the findings and recommendations and feel that the report satisfies the criteria for the Phase I evaluation. Minor comments have been discussed with your staff and we understand that these will be included in the final report.

Thank you for this opportunity to review and comment on the final draft report for this project.

Sincerely,

A handwritten signature in cursive script that reads "Richard L. Bondy".

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB/LT/mb



United States
Department of
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Soil
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P.O. Box 970
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June 27, 1980

Sidney Knutson, P.E.
Assistant Chief
Engineering Division
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, WA 98124

Dear Mr. Knutson:

Thank you for the opportunity to review the final draft report on the Higgins Brothers No. 1 Dam (MT-30).

No plans or records of the extent of SCS assistance in design, construction or repair can be found.

We cannot agree with the hydrology criteria used to develop the probable maximum flood.

Sincerely,

for Van K Haderlie
State Conservationist

cc:

Homer Moore, State Conservation Engineer, SCS, Bozeman
Dave Jones, Environmental Engineer, SCS, Bozeman



